

# **Reduced Complexity High Performance Array Processing**

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## **LONG TERM GOALS**

Improve passive sonar systems by fielding adaptive beamforming algorithms that are computationally efficient, that operate effectively during rapid array maneuvers, and are able to track and remove interference from fast-moving surface traffic.

## **OBJECTIVES**

Study a new approach to partially adaptive sonar signal processing and:

- Demonstrate its ability to solve matched field source localization problems.
- Compare its performance in acoustic waveguides to eigenvalue-based designs.
- Determine when and why nested Wiener filters outperform eigenvalue-based designs.

## **APPROACH**

This project is motivated by the signal processing needs of current and future Navy sonar arrays comprised of dozens or hundreds of sensors. Fully adaptive beamformers for such large arrays are impractical: they are too computationally demanding, and data adaptive implementations require too many independent, stationary samples.

“Partially adaptive” or “reduced complexity” adaptive beamformers can be used to contend with these difficulties [4]-[7]. It is well known that decreasing adaptive degrees of freedom reduces data requirements, speeds adaptation in dynamic environments, and reduces computational overhead. The best-known design techniques are based upon principal components analysis of estimated covariance matrices. However, they are computationally costly because of the eigenvalue decomposition, and their performance suffers drastically when the number of interference sources is larger than the number of adaptive weights.

A new approach based on a “nested” realization of the Wiener filter has the potential to solve these problems and is the focus of this project [8]. The design philosophy that underpins this structure is radically different from conventional techniques, because the cross-correlation structure of the data is explicitly incorporated into the design methodology from the onset. When applied to interference cancellers, the Wiener filter used to estimate and remove correlated noise is reformulated into a nested chain of first order filters, and in each subsequent stage, the data are projected onto subspaces spanned by a normalized cross-correlation vector and its null space. The net result is a low dimensional representation of the essential information in the secondary channel required to remove the correlated noise from the primary channel.

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The advantages of this design methodology are significant and have the potential to make a real difference to the Navy. First, explicit covariance matrix estimation and inversion are not required. Only scalar and vector quantities need be estimated. Second, designing a partially adaptive system is straightforward and does not require calculating eigenvalue decompositions. And finally, the initial results are most promising: it consistently outperforms eigenvalue-based designs, even when the adaptive degrees of freedom are less than the rank of the correlated interference.

## **WORK COMPLETED**

The nested filter has been implemented and tested on a matched field source localization problem and the preliminary results show excellent performance, even when the adaptive degrees of freedom are much less than the number of interference sources. The design was reformulated to solve least squares problems as well as statistically optimum problems. Finally, an analysis of the nested Wiener filter has been started in order to establish the conditions under which the nested processors consistently outperform eigenvalue-based designs.

## **RESULTS**

The algorithm has been implemented and tested in a simulated acoustic waveguide containing a submerged acoustic point source and nine close interference sources. The variance of the optimum processor's output was 11 dB. When the adaptive degrees of freedom were reduced from ten to four, the output variance of the eigenvalue-based designs was 11.8 dB. The variance of the nested Wiener filter processor was 11.1 dB. In the examples we have studied so far, we have found that the nested Wiener filter designs, exploiting the cross-correlation information in the data streams, outperform the eigenvalue-based designs.

## **IMPACT/APPLICATIONS**

This work applies to sonar systems requiring adaptive beamformers, including the Advanced Processing Build Program managed by ASTO and the ADS Program managed by PMW-183.

## **TRANSITIONS**

None. This is a basic research project and there are technical issues to resolve before transitioning this work to a 6.2 project.

## **RELATED PROJECTS**

Passive/Active Towed Volumetric Arrays [B2]  
Environment Based Wideband Matched Field Beamforming [B6]  
Environmentally Enhanced Array Processing [B7]  
Depth Discrimination with Horizontal Arrays [B9]  
Adaptive Array Processing in Shallow Water [B11]  
Signal Processing for Deployed Arrays [B12]

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## PATENTS

None.